Mass Wasting

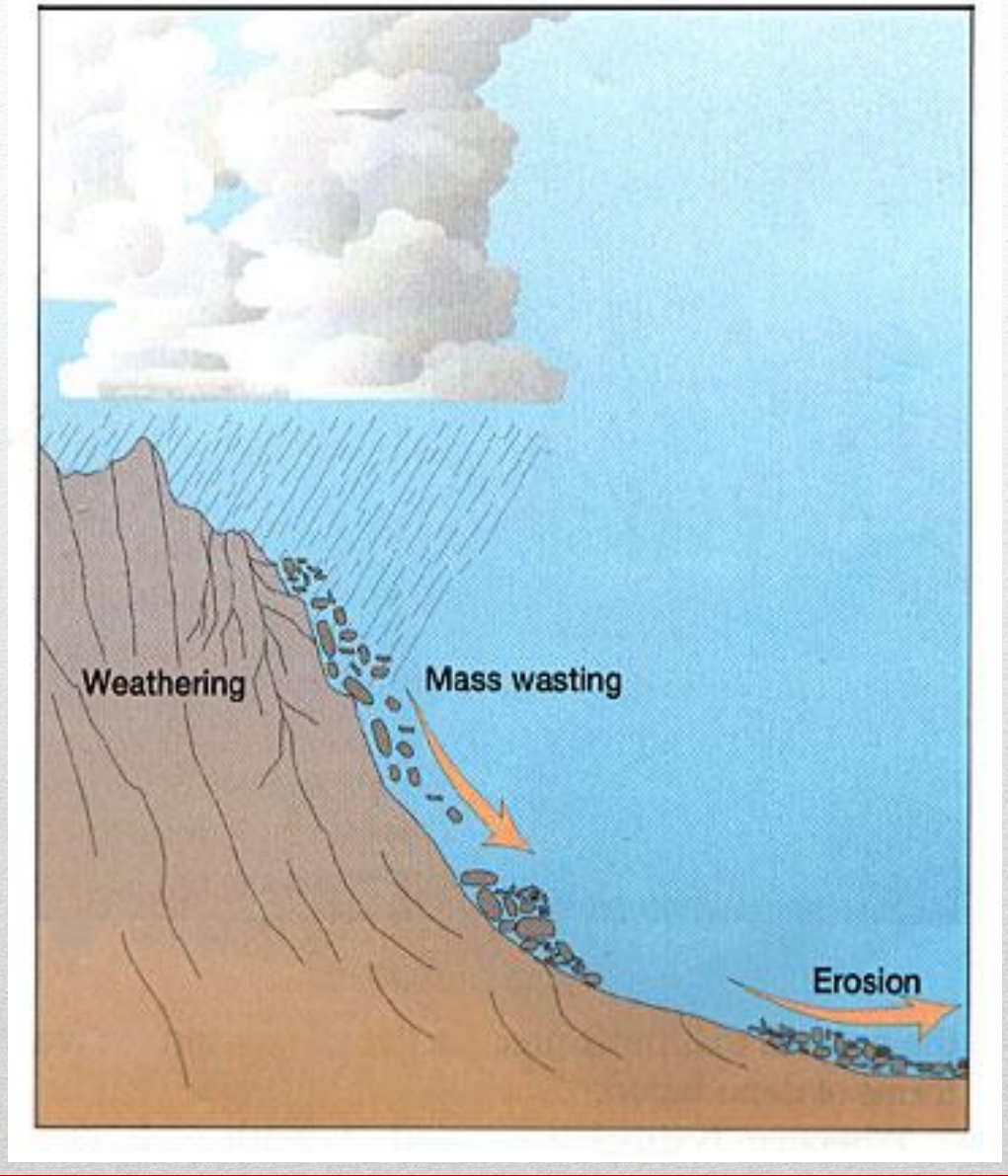
Chapter 7

Learning Objectives

- Understand slope processes and the different types of landsides
- Know the forces that act on slopes and how they affect the stability of a slope
- Know what geographic regions ore at risk from landslides
- Know the effects of landslides and their linkages with other natural hazards
- Understand how people can affect the landslide hazard
- Be familiar with adjustments we can make to avoid death and damage caused by landslides

Mass Wasting

- Mass Wasting is the rapid downslope movement of rock or soil as a more or less coherent mass. This will also include earthflows, debris flows, rock falls, and avalanches.
- **These will all be called <u>Landslides</u>**
- **The controls or causes of landslides are:**
  - **<u>Angle of Repose</u>** – the angle which cohesive layers of soil lie at rest on a slope if undisturbed unless the slope has a certain steepness.
  - **<u>Water</u>** – a lubricating medium that can diminished the friction between particles allowing easier sliding.
  - **<u>Clay</u>** – readily absorbs water allowing a spontaneously change from relatively solid mass to a near-liquid condition as result of a sudden disturbance or shock


Weathering
Mass wasting
Erosion

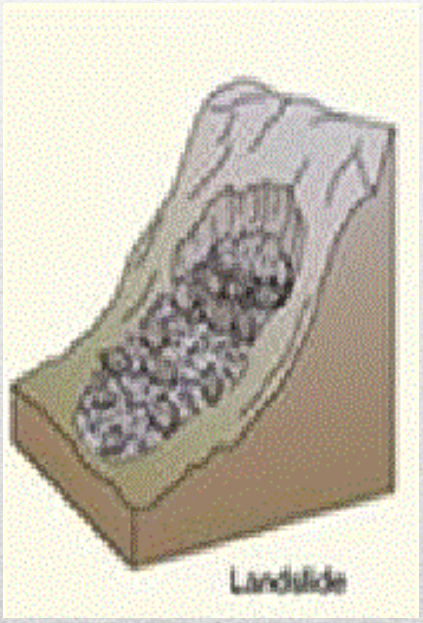
Types of Landslides

- **Fall** -- simplest and most obvious form of mass wasting: Material falling from the free face of a cliff

  - **Results of a Fall**
    - Talus or scree — debris of the fall
    - Talus cones -- mounds of debris at the bottom of a fall

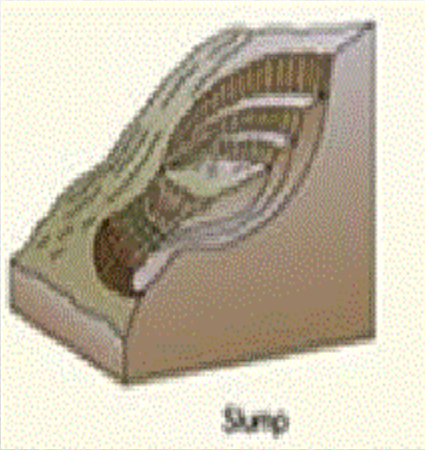
Types of Landslides

- **Slide** – an instantaneous collapse of a coherent block of earth material along a planar *slip plane*
  - On the hill were the slide originated, there is a deep extensive scar
  - In the valley bottom where the slide material comes to rest a massive pile of highly irregular debris
  - On the up-valley side of the debris, a lake may form



Types of Landslides

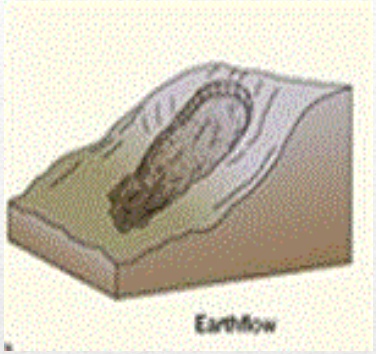
- **Slump** – involves slope failure in which the rock or regolith moves downward and at the same time rotates outward along a curved slide plane that produces *slump blocks*.

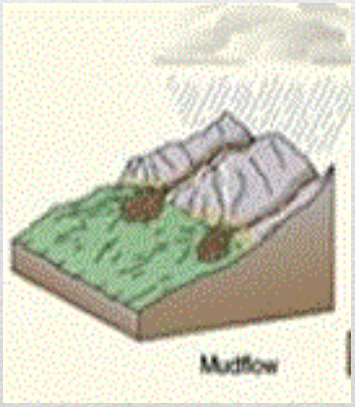


- **Flowage or Flow** the downslope movement of unconsolidated material in which particles move about mix within the mass
  - Examples: earthflows, debris flows, or avalanches

Types of Landslides

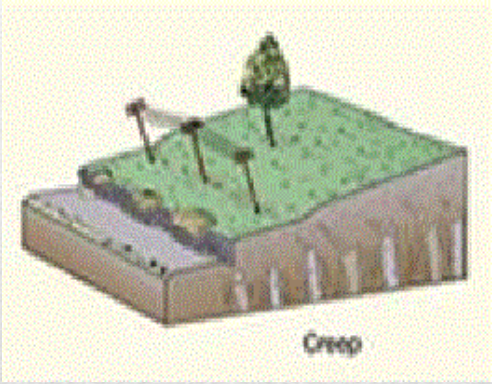
- **Earthflow** – a portion of a water-saturated slope moves a limited distance downhill, normally during or immediately after a heavy rain
- **Mudflow** – originates in drainage basins in arid and semiarid country when a heavy rain following a long dry spell produces a cascading runoff too voluminous to be absorbed into the soil
  - **Debris flow** -- debris carried by the mudflow, causing much damage
- **Avalanches**- either earth or snow





Types of Landslides

- **<u>Creep</u>** – consists of a very slow flowage which can progressively tilt telephone poles, fences, and tree trunks.
  - Caused by the interaction of various factors most significant being alternation of freeze-thaw and wet-dry conditions.
  - Very slow process. Can leave hillside ridges – *terracettes*



Downslope Movements on Slopes

- Downslope movements are classified according to four variables:
  1. The **mechanism of movement** (slide, fall, flow, or complex movement)
  2. **Type of earth material** (solid rock, soft consolidated sediment, or loose unconsolidated sediment)
  3. **Amount of water present**
  4. **Rate of movement** (movement is considered if it can be discerned with the naked eye, otherwise it is considered as “slow”)

Driving or Resisting Forces on Slopes

- **Forces on slopes: Look for relationship between**
  - The **driving forces** that move the materials
  - **Resisting forces** that oppose such movement
  - Most common driving force is the downslope component of the **weight of the slope material**
    - This weight can be from vegetation, fill material, or buildings
  - Most common resisting force is the **shear strength** of the slope material,
    - Its resistance to **failure by sliding or flowing along potential slip planes**
    - Potential slip planes are **geological surfaces of weakness** in the slope material such as bedding planes in sedimentary rocks and fractures in all types of rock

Forces on Slopes

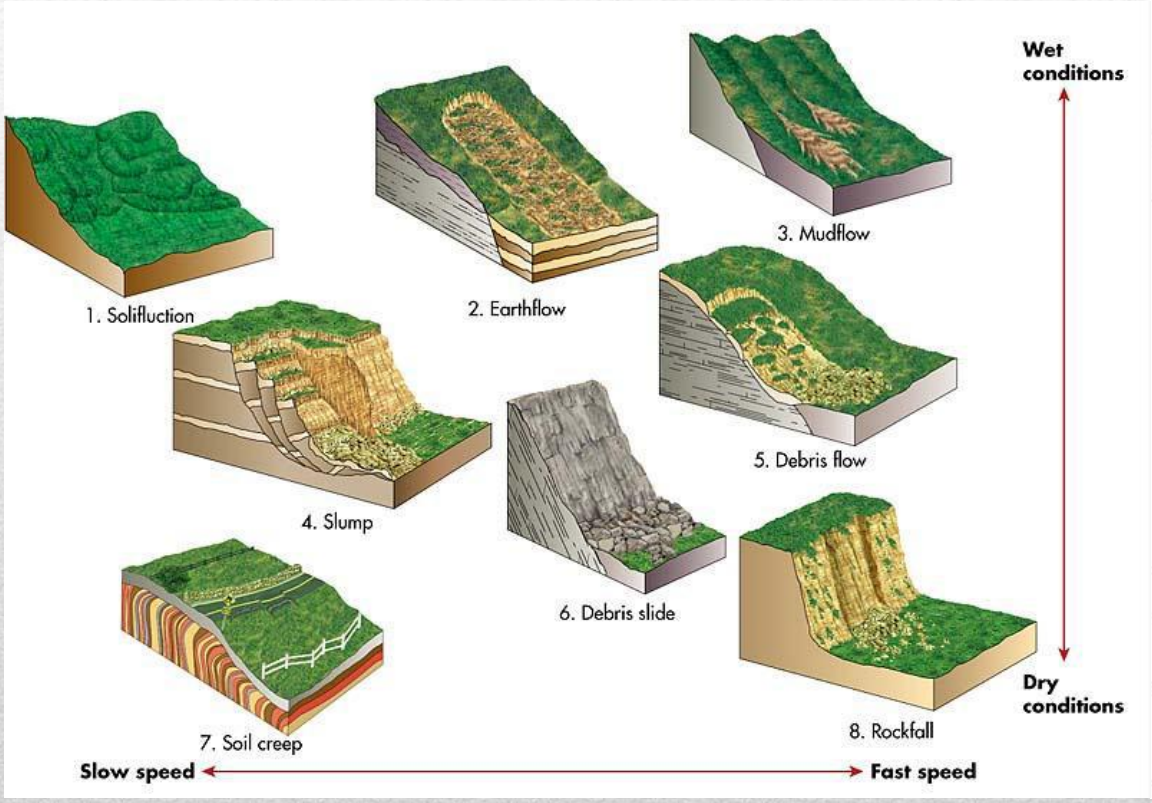
- **To determine the causes of landslides,** we examine the forces that influence the **slope stability**
- **Slope stability** is assessed by **determining the relationship** between **driving forces** that move the materials down a slope and the **resisting forces** that oppose such movement

  - The most common **driving force** is the downslope component of the weight of the slope material
    - The **weight** can be from anything superimposed or otherwise placed on the slope
  - The most common resisting force is the **shear strength** of the slope material
    - This is the **resistance** to failure by sliding or flowing along potential slip planes

Forces on Slopes

- **Slope stability** is evaluated by computing a **safety factor (SF)**
  - The **Safety Factor** is defined as **the ratio of the resisting forces to the driving forces**
    - If the **safety factor is greater than 1**, the **resisting forces exceed the driving forces**
    - If the **safety factor is less than 1**, the **driving forces exceed the resisting forces and slope failure can be expected**
- **These driving and resisting forces can change as conditions change**
- These **interrelationships** are controlled by these variables
  - Type of earth materials
  - Slope angle and topography
  - Climate
  - Vegetation
  - Water
  - Time

Types of Landslides And the Forces on them



Type of Movement	Materials	
	Rock	Soil
Landslides with variable water content and rate of movement	Rotational	
	Slump(a)	Slump(b)
	Translational	
	Rock slide(c)	Soil slide (slip)(d)
Falls	Rock fall(e)	Soil fall
Flows — Slow	Rock creep	Soil creep(f)
Flows	Unconsolidated rock and soil (saturated)	
Flows — Rapid	Earth flow(g)	
Flows — Rapid	Debris flow / mud flow(h)	
Flows — Very rapid	Debris avalanche(i)	
Lateral spread	Rock(j)	Soil
Subsidence	Rock(k)	Soil
Complex	Combination of slides, slumps, and flows(l)	

Driving and Resisting Forces

- **<u>These driving and resisting forces can change as conditions change</u>**

  These **<u>interrelationships</u>** are controlled by these variables

  - Type of earth materials
  - Slope angle and topography
  - Climate
  - Vegetation
  - Water
  - Time

Role of Earth Material Type

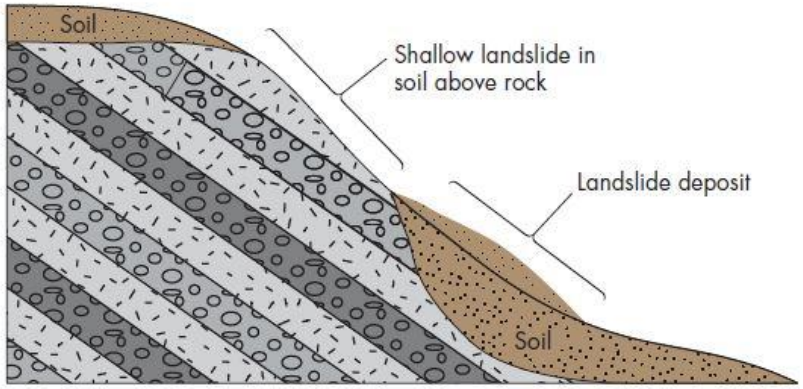
- **The Role of Earth Material Type**
  - The **material composition of a slope can affect both the type and the frequency of downslope movement**
  - The material characteristics include:
    - **Mineral composition**
    - **Degree of cementation or consolidation**
    - The **presence of zones of weakness**
    - The **ability of the earth material to transmit water**
  - These **characteristics are connected with different kind of rock over which they lie**

Role of Earth Material Type

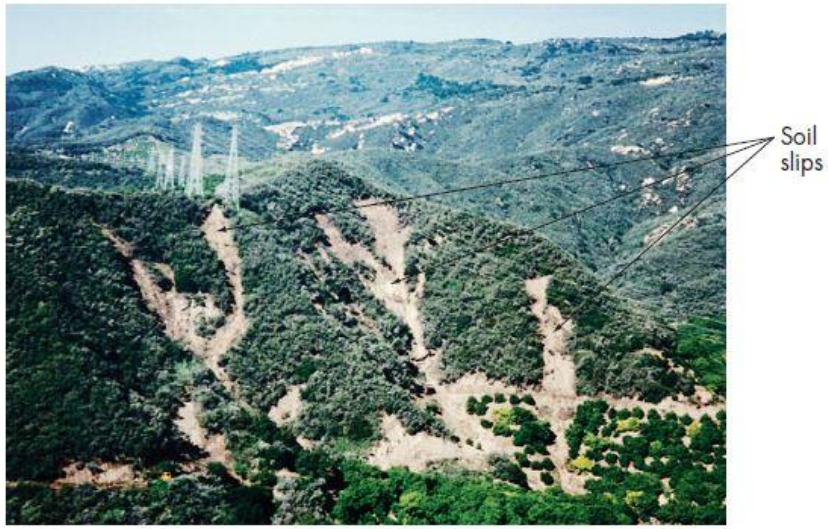
- Weak zones can be hazardous if the **zone or plane intersects the slope of a hill or mountain**
  - Where these are rock bedding planes, they are referred to as **daylighting beds**
- For Slides, the shape of the **slip surface** Is strongly controlled by the type of earth material
- There are two basic patterns of movement, **rotational** and **translational**
  - **Rotational slides or slumps** have curved slip surfaces
  - **Transitional slides** generally have planar slip surface

Role of Slope and Topography

- Two factors are important with **slope and topography**
  - **Steepness and amount of topographic relief**
    - **Slope** – the slant or incline of the land surface
    - **Relief** – refers to the height of the hill or mountain above the land below
  - **Debris flows** – are thick mixtures of mud, debris, and water
    - Range in consistency from thick mud soups to wet concrete and are capable of carrying house-size boulders
    - They can move slowly or rapidly depending on conditions


Soil
Shallow landslide in soil above rock
Landslide deposit
Soil

(a)


Soil slips

(b)

Role of Climate

- **The Role of Climate**
  - **Climate is defined as typical weather in an area over a period of years or decades or centuries**
  - It is **more than just the average of temperature and precipitation**
    - Includes kinds of **precipitation** and its **seasonal patterns**
    - **These patterns effect other factors of these forces**
    - **Seasonal patterns effect the vegetation, soils, and bare rocks**
    - **Dry areas are much different than wet areas**

The Role of Vegetation

- **The Role of Vegetation**
  - **Complex role in the development of landslides and related phenomena**
  - The **nature of vegetation in an area is a function of climate, soil type, topography, and fire history, each of which influences what happens on slopes**
  - **Vegetation is significant factor in slope stability for three reasons:**
    - **Vegetation provides a protective cover that cushions the impact of falling rain.** This cushion allows the water to infiltrate the slope while retarding the surface erosion
    - **Plant roots add strength and cohesion to slope material materials.** They act like steel rebar reinforcements in concrete and increase the resistance of a slope to sliding
    - **Vegetation also adds weight to a slope**

The Role of Water

- **The Role of Water**
  - Water is almost **always directly or indirectly involved with landslides**
  - When studying a **landslide, scientists first examine what water is both on and within the slope**
  - **Water affects slope stability in three basic ways**:
    1. **Many landslides**, such as shallow soil slips and debris flows, **develop during rainstorms when slopes become saturated**
    2. **Other landslides, such as slumps**, develop months or even years following the deep infiltration of water into a slope
    3. **Water erosion of the base or toe of a slope** decreases its stability

The Role of Time

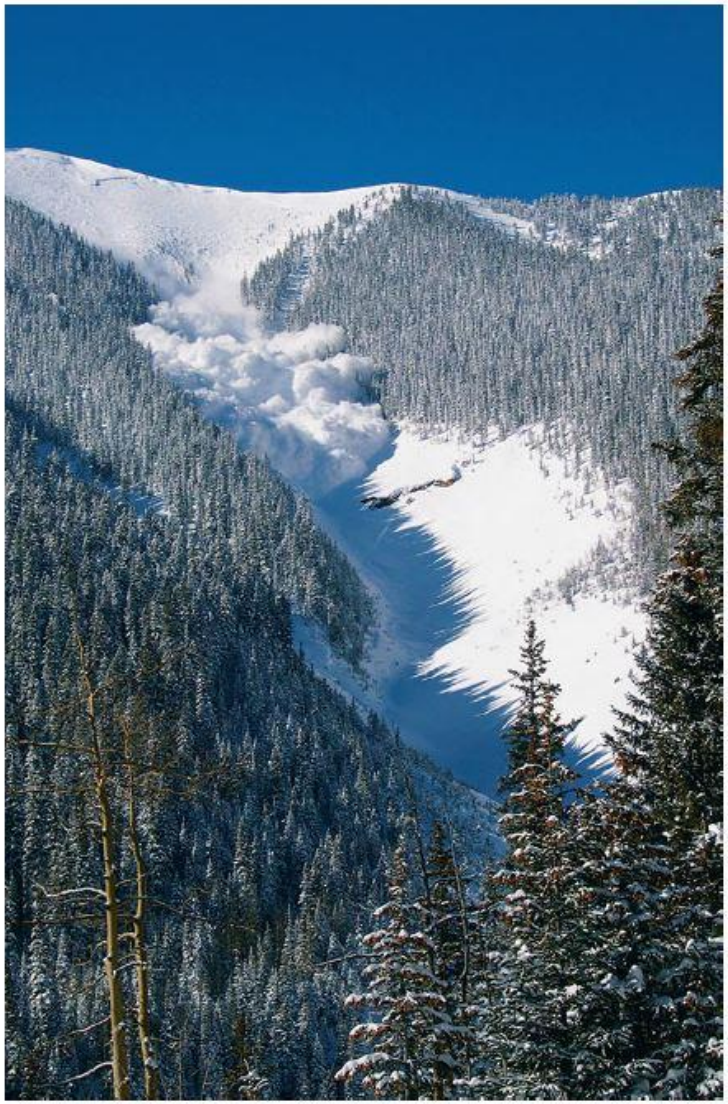
- **The Role of Time**
  - The **forces acting on slopes often change with time**
    - Example: both driving and resisting forces may change seasonally with fluctuations in the moisture content of the slope or with changes in the position of the water table
  - Much of the **chemical weathering of rocks, which reduces their strength**
    - This happens soil water is often acidic because it produces weak carbonic acid
    - In wet years the chemical reaction is greater, there is more chances to for the slope to slump

(a)

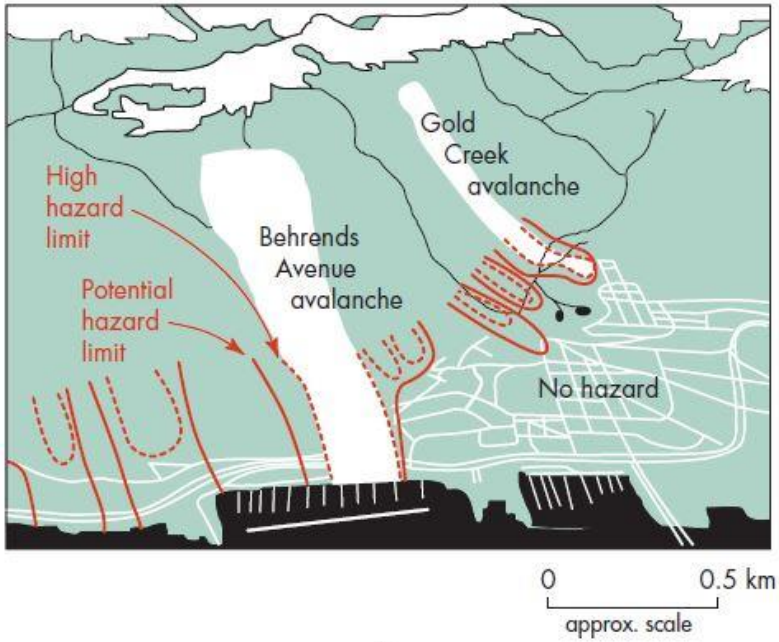
(b)

Snow Avalanches

- **Snow Avalanches**
- **A rapid downslope movement of snow and ice, sometimes with the addition of rock, soil, and vegetation**
- **Thousands happen all over the world** where there are slopes which accumulate snow during the winter
- The **steeper the slope, the more chance for an avalanche**
- There are **two kinds of avalanches**
  - **Loose-snow avalanches** – start a point and widen as they progress down the slop
  - **Slab Avalanches** – start as a cohesive blocks of snow and ice the move downslope
    - These avalanches are triggered by the **overloading of a slope or the development of zones of weakness** in the snowpack



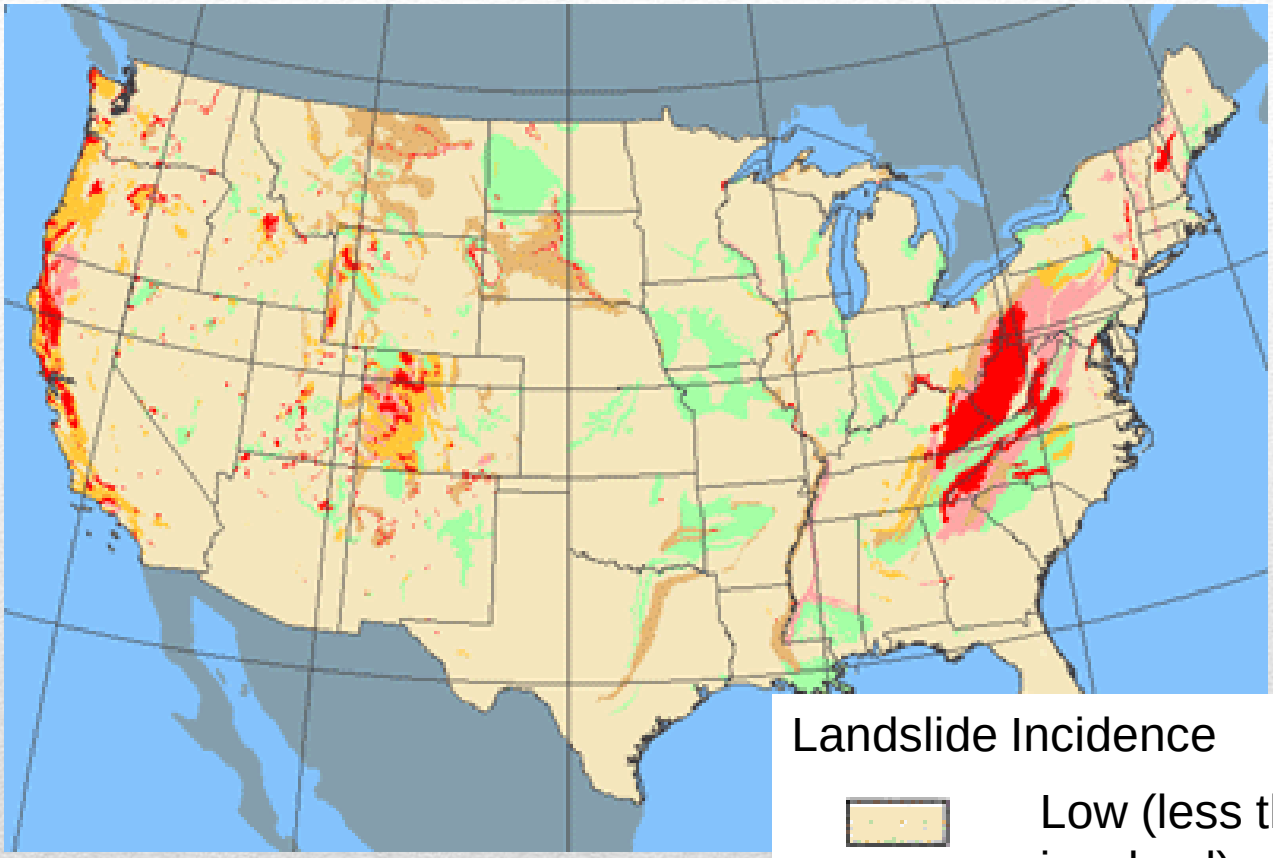
(a)


Gold
Creek
avalanche
High
hazard
limit
Behrends
Avenue
avalanche
Potential
hazard
limit
No hazard
0
0.5 km
approx. scale

(b)

Geographic Regions at Risk from Landslides

- **Landslides occur everywhere there are significant slopes and mountains**
- There are **three factors** which expect to increase worldwide landslide activity
  - **Urbanization and development will expand in landslide-prone areas**
  - **Tree cutting will continue in landslide-prone areas**
  - **Changing global climate patterns will result in regional increases in precipitation**


Landslide Incidence
Low (less than 1.5% of area involved)
Moderate (1.5%-15% of area involved)
High (greater than 1

Effects of Landslides and Linkages with other Natural Hazards

- **Effects of Landslides**
  - Landslides and related phenomena have the capacity to cause substantial damage and loss of life
  - Direct effects of landslides on people and property include being hit with or buried in falling debris
  - Landslides may also damage homes, roads, and utilities that have been constructed on the top or side of a hill
  - Indirect effects include flooding upstream and transmission of disease
- **Linkages Between Landslides and Other Hazards**
  - Landslides and other types of mass movement are linked to almost every other natural hazard
  - Earthquakes, volcanoes, storms, and fires all have the potential to cause landslides

Natural Service Functions of Landslides

- It is hard to imagine **natural service functions coming from landslides**
  - But there are a few, to an old-growth forest, a slide can be beneficial by:
    - **Increasing both plant and animal diversity.**
    - **In aquatic environments, damned lakes create new habitat for fish and other organisms**

- **Human Interaction with Landslides**
  - **Landslides and other natural ground fractures would happen with or without human intervention**
  - **Human intervention has increased the chance of a landslide by**:
    - Timber Harvesting and Landslides
    - Urbanization and Landslides

Minimizing the Landslide Hazards

- **Minimizing the Landslide Hazards**
  - **It's necessary to identify the areas where landslides can occur**, design slopes, or engineering structures to prevent landslides
  - **Warn people of impending slides, and control slides after they have started moving**
- **Identification of Potential Landslides by their features**
  - Crescent-shaped cracks or terraces on a hillside
  - A tongue-shaped area of bare soil or rock on a hillside
  - Large boulders or talus piles at the base of a cliff
  - A linear path of cleared or distributed vegetation extending down a hillslope
  - Tongue-shaped masses of sediment, especially gravel, at the base of a slope or at the base of a slope or a the mouth of a valley
  - An irregular, often referred to as hummocky, land surface at the base of a slope

Minimizing the Landslide Hazards

- **Identification of Potential Landslides**
  - **Prevention of large, natural landslides is difficult, but common sense and good engineering practices can help minimize the hazard**
  - **Prevention of Landslides**
    - **Drainage Control**
      - Surface and subsurface drainage control is usually effective in stabilizing a slope
      - Divert the water away from the slope by a series of drains
    - **Grading**
      - Although grading in some instances increases the chance of landslide, planned grading can increase the stability
    - **Slope Supports**
      - Most common methods of stabilization is building a retaining wall

Minimizing the Landslide Hazards

- **Use of a Landslide Warning System**
  - **Do not prevent landslides**, but they can provide time to evacuate people and their possessions
  - **Time to stop trains or reroute traffic**
  - **Surveillance of hazardous areas can be inspected for apparent changes**
  - **Other methods surveillance include electrical systems, tiltmeters, and geophones that pick up vibrations of moving soils**

Perception of and Adjustment to the Landslide Hazard

- **Perception of the Landslide Hazard**
  - It can **never happen** on this slope
  - **Mapping does not guarantee people will listen**
- **Adjustments to the Landslide Hazard**
  - Although, **best practice would be to not build in slide prone areas, people still do**
  - **Siting of Critical Facilities**
    - **Critical Facilities should not be placed over landslide areas**
  - **Landside Correction**
    - **After a landslide begins the best way to stop it is to attack the process that started it**
      - **Working with the slope and the water causing the slide**
  - **Personal Adjustments:**
    - **What You Can Do To Minimize Your Landslide Hazard**